EXTRACTING 3-D CURVATURES FROM IMAGES OF SURFACES USING A NEURAL MODEL. Sidney R. Lehky * and Terrence J. Sejnowski. (SPON: G. F. Poggio). Department of Biophysics, Johns Hopkins University, Baltimore, MD 21218.

Many neurons in primary visual cortex have oriented receptive fields, and consequently are often interpreted as "bar detectors" or "edge detectors". However, in addition to edges, there is significant information contained in the continuous gradations of shading within an image. We have investigated this by constructing a computer model of a neural network that extracts curvatures from the shading information contained in images of simple geometrical surfaces. Specifically, the network determines the principal curvatures (largest and smallest curvatures) at the center of the surface, and their orientation, independent of illumination direction, and the precise location of the surface within the overall receptive field of the network. The network, which is meant to reflect processing occuring within a single cortical column, has model neurons arranged in three layers. Each unit within a layer is synaptically connected to every unit of the next layer. The input layer is an hexagonal array of overlapping, circularly-symmetric, center-surround units with both ON and OFF centers. The output layer is a set of units in which each unit is broadly tuned to both principal curvature, and the orientation of that curvature. Therefore, the activity of a single output unit is ambiguous, and the output information is contained in the joint activities of the output units. Finally, there is the middle, or "hidden unit" layer, which transforms the retinotopic coordinates of the input layer to the curvature-orientation coordinates of the output layer.

We used the "back-propagation" learning algorithm[1] as a design technique to construct a network with the desired characteristics. The network was presented with many sample images, and for each presentation, the actual responses of the output units were compared with the correct output. Then the synaptic weights throughout the network were slightly modified to reduce the error. Following this procedure, the individual units within the hidden layer formed a variety of receptive fields, mostly oriented but a few non-oriented. The response properties of the units were mapped out using "simulated neurophysiology". Using bars of light as stimuli, the oriented hidden units appeared to have characteristics of simple cells. The output units, which receive input from many hidden units, appeared to have some properties of complex cells. We conclude that neurons which can extract curvature can have receptive field properties similar to those which previously were interpreted as bar or edge detectors. Yet other interpretations may be possible. The receptive field properties of a sensory neuron are necessary but not sufficient to determine its function within a network.

[1]Rumelhart, D., Hinton, G., and Williams, R. (1986) *Nature* 323, 533-536.